FOURIER TRANSFORM INFRARED DIAGNOSTICS FOR IMPROVED FIRE DETECTION SYSTEMS

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A major advance in the past two decades is the availability of low cost smoke detectors based on either ionization or photoelectric detectors. However, these detectors have some drawbacks because of the high frequency of false alarms. Other types of detector technologies have been developed for specific gases, such as CO_2, CO, or O_2, based on metal oxide semiconductors, electrochemical sensors, or optical sensors. However, all single parameter methods are hindered by the lack of generality for several types of fires and a lack of "intelligence," i.e., not always being able to discriminate against false signals (1-3). The objective of this study was to demonstrate the feasibility of an Fourier Transform Infrared (FT-IR) spectroscopy based fire detection system. This work involved four tasks: 1) modification of an FT-IR spectrometer system to investigate three different detection modes (open-path, cross-duct, extraction into a multi-pass cell); 2) FT-IR measurements in the three modes for several types of flames; 3) investigation of advanced signal processing techniques for data analysis; 4) preliminary design of a prototype fire detection system. The types of fires examined included polymethyl methacrylate (PMMA), polystyrene (PS), polyvinyl chloride (PVC), polyurethane, douglas fir, methanol, hexane and heptane.

The FT-IR measurements for CO, CO_2, and total hydrocarbons were found to follow similar trends as the measurements of single parameter instruments and good quantitative agreement was obtained in most cases, as shown in Figure 1. The extractive FT-IR measurements provided significant amounts of additional data on pre-ignition and combustion products including: monomeric species, unburned fuel, oxygenates (methanol, formaldehyde, dimethyl ether), olefins (ethylene, acetylene), pyrolysis products (CH_4, HCN) and combustion products (H_2O, NO, N_2O). Cross-duct measurements were made for selected samples (PVC, douglas fir) which allowed for measurement of HCl and smoke, which were not seen with the extractive system in which a filter was placed in front of the gas cell (see Figure 1). A third set of measurements was done on a similar sample set using open-path FT-IR measurements in a 600 ft^3 combustion facility that was ventilated at rates of 100-400 ft^3/min. Using an optical path of 2.2 meters, good sensitivity was found for most of the same compounds observed in the cross-duct and extractive measurements. A conventional smoke alarm and was placed in close proximity to the beam path. In all cases, the FT-IR system was more sensitive to the formation of combustion products (CO_2, CO, H_2O) than the smoke alarm, although it is recognized that such alarms are desensitized due to their inherent lack of selectivity.

The results of the experimental measurements indicated that FT-IR spectroscopy offers significant capabilities for development of improved fire detection systems including: 1) detection of volatile fuel prior to ignition; 2) detection of pyrolysis products prior to ignition and during the early stages of combustion; 3) detection of multiple indicators of combustion which are not easily detected by other means and which are fuel specific; 4) simultaneous detection of non-specific indicators of combustion (CO, CO_2, H_2O) and smoke with a single instrument. The implementation of an advanced fire detection system requires a data analysis scheme which can: 1) quantify the gas and smoke concentrations; 2) apply a decision algorithm to determine if a fire condition is present. It was concluded based on the preliminary data that a rule based approach would be the best starting point for the alarm logic software. This could be made more robust by the use of fuzzy logic and made to be adaptive by the use of neural networks.

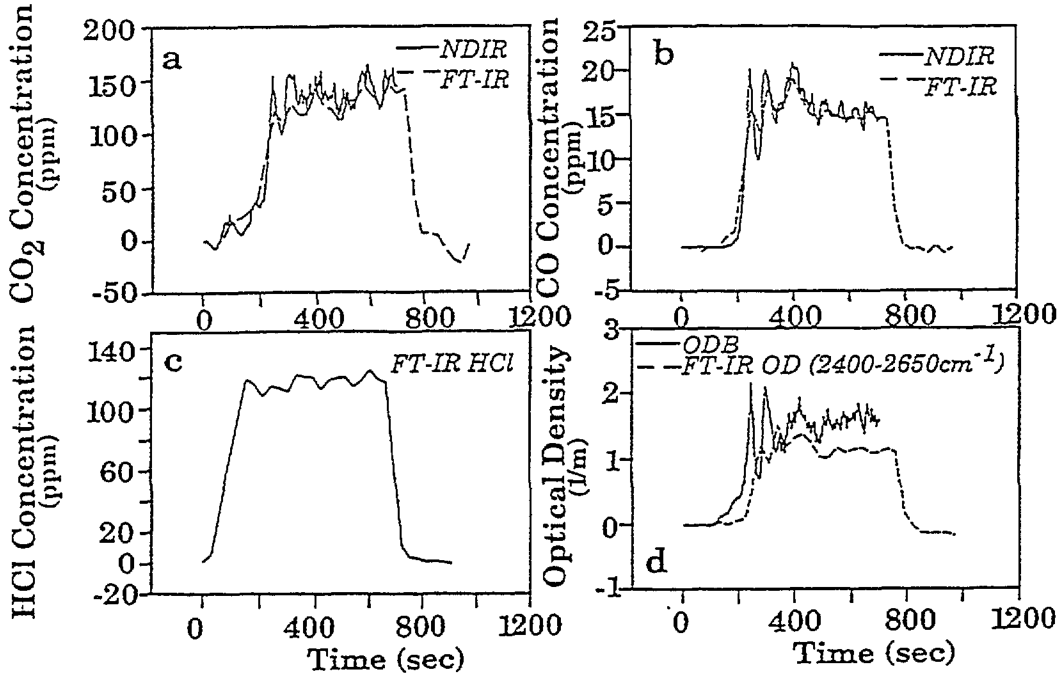

Figure 1. Comparison of Cross-Duct FT-IR and Extractive NDIR Data for a) CO_2; b) CO; c) HCl; and d) Optical Density from a PVC Fire Test.

The successful development of FT-IR based fire detection systems would find immediate application in high value content buildings such as computer rooms, telephone central office exchanges, clean rooms, hospitals, museums, libraries, military installations, etc. This work will also establish a technology base which will lead to the development of improved, low cost IR systems.

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